

CLAIMS

1. A thin film piezoelectric device including a substrate having a plurality of vibration spaces and a piezoelectric laminated structure formed on the substrate, a plurality of thin film piezoelectric resonators being formed facing the vibration spaces,

wherein the piezoelectric laminated structure has at least a piezoelectric film and a metal electrode formed on at least a part of each of opposite surfaces of the piezoelectric film,

the piezoelectric laminated structure comprises diaphragms positioned facing the vibration spaces, and a support area other than the diaphragms,

at least one set of two adjacent thin film piezoelectric resonators are electrically connected to each other through the metal electrode,

the thin film piezoelectric device comprising at least one set of two adjacent thin film piezoelectric resonators in which D0 is a distance between the centers of the diaphragms of the two electrically connected adjacent thin film piezoelectric resonators and D1 is a length of a segment of a support area on a straight line passing through centers of the diaphragms of two electrically connected adjacent thin film piezoelectric resonators, and a ratio D1/D0 is 0.1 to 0.5.

2. The thin film piezoelectric device according to claim 1, wherein the ratio D1/D0 is in a range of 0.1 to 0.5 with respect to all the sets of two electrically connected adjacent thin film piezoelectric resonators.

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3. The thin film piezoelectric device according to claim 1,  
wherein each of the vibration spaces is formed by a via hole extending  
from the surface of the substrate on which the piezoelectric laminated  
structure is formed to the opposite surface, and a side wall surface  
of the via hole forms a slant angle in a range of 80 to 100° with  
respect to the surface of the substrate on which the piezoelectric  
laminated structure is formed.

4. The thin film piezoelectric device according to claim 1,  
wherein the piezoelectric laminated structure comprises a lower  
electrode constituting the metal electrode, the piezoelectric film,  
and an upper electrode constituting the metal electrode stacked in  
order from the substrate side in at least one thin film piezoelectric  
resonator.

5. The thin film piezoelectric device according to claim 4,  
wherein the upper electrode of the at least one thin film  
piezoelectric resonator comprises two electrode portions.

6. The thin film piezoelectric device according to claim 1,  
wherein the piezoelectric laminated structure comprises a lower  
electrode constituting the metal electrode, a first piezoelectric film,  
an inner electrode constituting the metal electrode, a second  
piezoelectric film, and an upper electrode constituting the metal  
electrode stacked in order from the substrate side in at least one  
thin film piezoelectric resonator.

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7. The thin film piezoelectric device according to claim 1, wherein at least one insulating layer of silicon oxide and/or silicon nitride as a main component is attached to the diaphragm.

5 8. The thin film piezoelectric device according to claim 1, wherein an insulating layer comprising at least one layer of silicon oxide and/or silicon nitride as a main component intervenes only between the support area of the piezoelectric laminated structure and the substrate.

0 9. The thin film piezoelectric device according to claim 1, wherein the piezoelectric film is an oriented crystal film represented by a general formula  $Al_{1-x}Ga_xN$  (where  $0 < x < 1$ ) and consists of a solid solution of aluminum nitride and gallium nitride showing a c-axis orientation, and a rocking curve half value width (FWHM) of a diffraction peak of a (0002) surface of the film is  $3.0^\circ$  or less in at least one thin film piezoelectric resonator.

5 10. The thin film piezoelectric device according to claim 1, wherein the piezoelectric film is a zinc oxide thin film showing a c-axis orientation, and a rocking curve half value width (FWHM) of a diffraction peak of a (0002) surface of the film is  $3.0^\circ$  or less in at least one thin film piezoelectric resonator.

5 11. The thin film piezoelectric device according to claim 1, wherein the piezoelectric film is a lead titanate thin film or a lead zirconate titanate thin film in at least one thin film piezoelectric resonator.

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12. The thin film piezoelectric device according to claim 1,  
wherein the planar shape of one of the diaphragms has two pairs of  
opposite sides, and at least one pair of opposite sides is formed to  
5 be non-parallel in at least one thin film piezoelectric resonator.

13. The thin film piezoelectric device according to claim 1,  
wherein at least a part of the planar shape of one of the diaphragms  
is formed by a non-square irregular polygonal shape in at least one  
0 thin film piezoelectric resonator.

14. The thin film piezoelectric device according to claim 1,  
wherein the planar shape of one of the diaphragms is formed by a non-  
square irregular polygonal shape including a curved portion in at  
5 least a part of the shape in at least one thin film piezoelectric  
resonator.

15. The thin film piezoelectric device according to claim 1,  
the thin film piezoelectric device being a thin film piezoelectric  
0 filter.

16. The thin film piezoelectric device according to claim  
15, wherein the thin film piezoelectric filter comprises a ladder type  
circuit comprising a plurality of thin film piezoelectric resonators  
5 connected in series and at least one of the thin film piezoelectric  
resonators branched from/connected to the plurality of resonators  
connected in series.

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17. The thin film piezoelectric device according to claim 1, the thin film piezoelectric device being a duplexer comprising a plurality of thin film piezoelectric filters.

5 18. The thin film piezoelectric device according to claim 17, wherein the thin film piezoelectric filter comprises a ladder type circuit comprising a plurality of thin film piezoelectric resonators connected in series and at least one of the thin film piezoelectric resonators branched from/connected to the plurality of resonators  
0 connected in series.

19. A method of manufacturing the thin film piezoelectric device according to claim 1, comprising the steps of: forming the piezoelectric laminated structure on the substrate comprising a  
5 semiconductor or an insulator; and thereafter forming the vibration spaces in the substrate from a side opposite to the side on which the piezoelectric laminated structure is fabricated by a deep graving type reactive ion etching process.

0 20. A thin film piezoelectric resonator formed using a substrate having a vibration space, and a piezoelectric laminated structure formed on the substrate, wherein the piezoelectric laminated structure comprises at least a piezoelectric film and a metal  
5 electrode formed on at least a part of each of the opposite surfaces of the piezoelectric film, the vibration space is formed by a via hole extending from the surface of the substrate on which the piezoelectric laminated structure is formed to an opposite surface, and a side wall surface of the via hole forms an angle in a range of 80 to 100° with

respect to the surface of the substrate on which the piezoelectric laminated structure is formed.

21. (Added) The thin film piezoelectric resonator according to claim 20, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and the upper electrode comprises two electrode portions.

22. (Added) The thin film piezoelectric resonator according to claim 20, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, a first piezoelectric film, an inner electrode constituting the metal electrode, a second piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side.

23. (Added) The thin film piezoelectric resonator according to claim 20, wherein at least one insulating layer of silicon oxide and/or silicon nitride as a main component is attached to the diaphragm.

24. (Added) The thin film piezoelectric resonator according to claim 23, wherein assuming that a thickness of the piezoelectric film is  $t$ , and a thickness of the insulating layer is  $t'$ ,  $0.1 \leq t'/t \leq 0.5$  is satisfied.

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25. (Added) The thin film piezoelectric resonator according to claim 20, wherein at least one insulating layer of silicon oxide and/or silicon nitride as a main component intervenes only between a support area of the piezoelectric laminated structure and the substrate.

26. (Added) The thin film piezoelectric resonator according to claim 20, wherein the piezoelectric film comprises: a film made of zinc oxide; a film made of lead titanate; a film made of lead zirconate titanate; or an oriented crystal film represented by a general formula  $Al_{1-x}Ga_xN$  (where  $0 < x < 1$ ) and made of a solid solution of aluminum nitride and gallium nitride.

27. (Added) The thin film piezoelectric resonator according to claim 20, wherein the planar shape of the diaphragm has two pairs of opposite sides, and at least one pair of opposite sides is formed to be non-parallel.

28. (Added) The thin film piezoelectric resonator according to claim 20, wherein at least a part of the planar shape of the diaphragm is formed by a non-square irregular polygonal shape.

29. (Added) The thin film piezoelectric resonator according to claim 20, wherein the planar shape of the diaphragm is formed by a non-square irregular polygonal shape including a curved portion in at least a part of the shape.

30. (Added) The thin film piezoelectric resonator

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according to claim 20, wherein at least one of metal electrodes comprises a main electrode layer and an adhesive layer.

31. (Added) The thin film piezoelectric resonator  
5 according to claim 20, wherein a thickness of the piezoelectric film is in a range of 0.98 to 1.57  $\mu\text{m}$ .

32. (Added) The thin film piezoelectric resonator  
according to claim 20, wherein the piezoelectric laminated structure  
0 comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and a total of thicknesses of the lower electrode and the upper electrode is in a range of 320 to 485 nm.

5 33. (Added) The thin film piezoelectric resonator according to claim 32, wherein a thickness of the lower electrode is in a range of 170 to 235 nm.

0 34. (Added) The thin film piezoelectric resonator according to claim 32, wherein a thickness of the upper electrode is in a range of 150 to 250 nm.

5 35. (Added) The thin film piezoelectric resonator according to claim 20, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and a ratio of a

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total of thicknesses of the lower electrode and the upper electrode to a thickness of the piezoelectric film is in a range of 0.255 to 0.392.

36. (Added) The thin film piezoelectric resonator according to claim 30, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and a ratio of a total of thicknesses of the lower electrode and the upper electrode to a thickness of the piezoelectric film is in a range of 0.255 to 0.452.

37. (Added) The thin film piezoelectric device according to claim 2, wherein the ratio  $D1/D0$  is in a range of 0.18 to 0.3 with respect to all the sets of two electrically connected adjacent thin film piezoelectric resonators.

38. (Added) The thin film piezoelectric device according to claim 7, wherein assuming that a thickness of the piezoelectric film is  $t$ , and a thickness of the insulating layer is  $t'$ ,  $0.1 \leq t'/t \leq 0.5$  is satisfied.

39. (Added) The thin film piezoelectric device according to claim 1, wherein at least one of metal electrodes comprises a main electrode layer and an adhesive layer.

40. (Added) The thin film piezoelectric device according to claim 1, wherein a thickness of the piezoelectric film is in a range of 0.98 to 1.57  $\mu\text{m}$ .

41. (Added) The thin film piezoelectric device according to claim 1, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and a total of thicknesses of the lower electrode and the upper electrode is in a range of 320 to 485 nm.

42. (Added) The thin film piezoelectric device according to claim 41, wherein a thickness of the lower electrode is in a range of 170 to 235 nm.

43. (Added) The thin film piezoelectric device according to claim 41, wherein a thickness of the upper electrode is in a range of 150 to 250 nm.

44. (Added) The thin film piezoelectric device according to claim 1, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked in order from the substrate side, and a ratio of a total of thicknesses of the lower electrode and the upper electrode to a thickness of the piezoelectric film is in a range of 0.255 to 0.392.

45. (Added) The thin film piezoelectric device according to claim 39, wherein the piezoelectric laminated structure comprises a lower electrode constituting the metal electrode, the piezoelectric film, and an upper electrode constituting the metal electrode stacked

in order from the substrate side, and a ratio of a total of thicknesses of the lower electrode and the upper electrode to a thickness of the piezoelectric film is in a range of 0.255 to 0.452.

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